Inventing a Cooler, and Cleaner, Future

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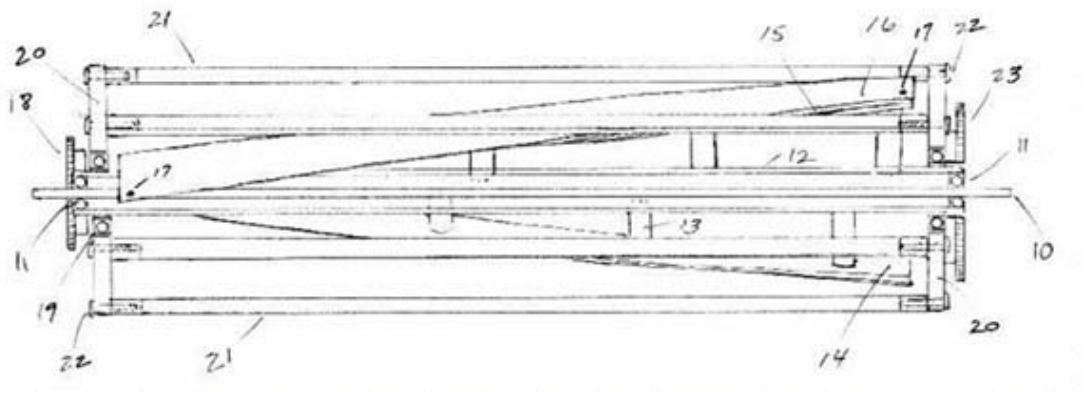
O-Sage Power Equipment LLC

Air Resources Board
ICAT Seminar Presentation
Nov. 23, 2009



Funded by a grant from ARB's Innovative Clean Air Technologies program

Agenda

- Current technology
- Technology drawbacks
- O-Sage concept
- Prototype development
- Performance testing
  - Cut quality
  - Energy efficiency
    - Test #1
    - Test #2
  - Reliability
- Discussion

This is not a green lawnmower

Is 2hp really needed?

Is 6+hp?

Why so much power?

Rotary mowers

- Very high speeds (3,000+rpm) and power level to cut with *purely inertial force*

- Power required increases with square of blade length
  - explains why rotary electric mowers are smaller than gas mowers

(Largest electric ≈1hp at full capacity*)

*1hp=746W

Other rotary mower drawbacks

Safety is an issue,
for people and grass

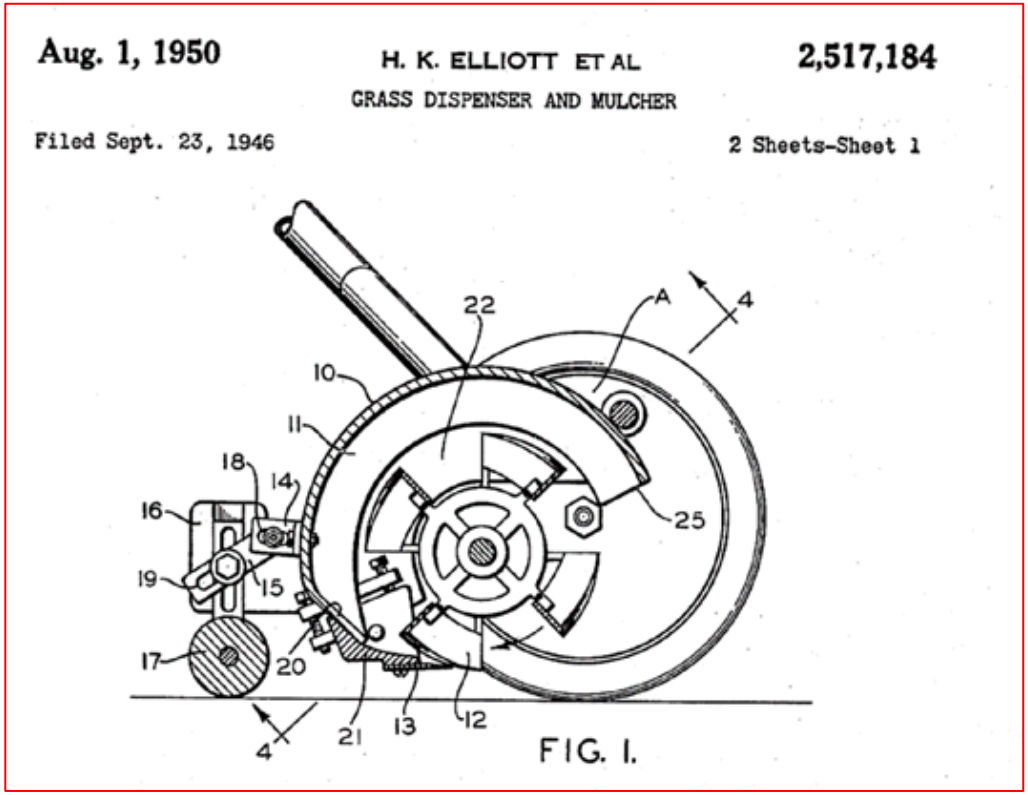
There is an alternative

Reel mowers –

- Lower energy requirements because they cut like a scissors
- But they require precision set-up and maintenance.
- And they can't mulch

Can a reel mower mulch?

Many previous ideas for redirecting clippings back into cutter:



They didn't work.

O-Sage design objectives

- Clean cut – as good as reel mower
- Mulches
- Fraction of energy used by rotary mowers
- Battery power for use on larger yards (½ acre)
- Cutting head as wide – or wider – than rotary mowers
- Easy to Use
  - Instant stop/start, maneuverable, stores in less space, etc.
- Safer than rotary mower
- Self-sharpening, easily replaceable, *proprietary* blades
- No more expensive than mid-priced rotary mower

Feb., 2005

Basic O-Sage concept

Cut grass between reel bar and *multiple* blades counter-rotating *inside* the reel

- Puts cutting edge on inner surface of reel bar.

Use *flexible* blades to allow for minor misalignment

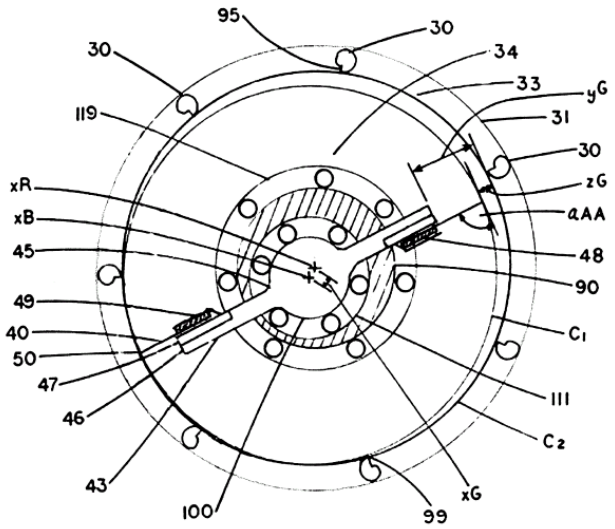


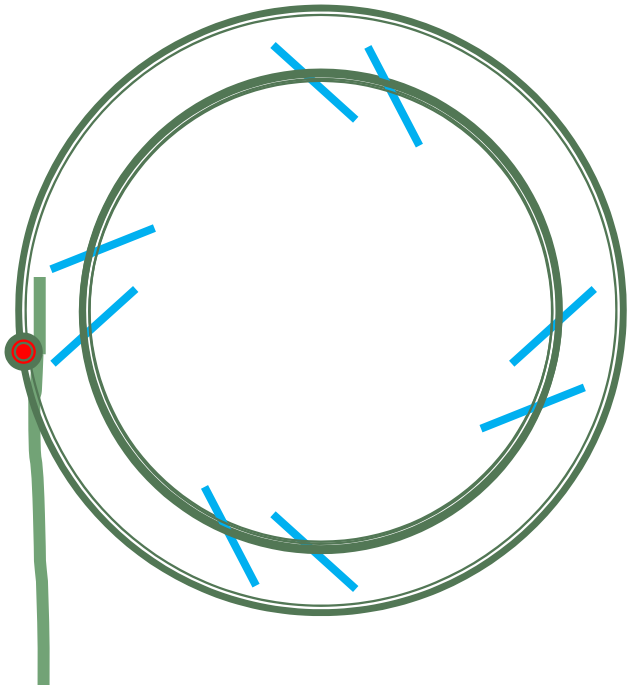
FIG. 5

Basic O-Sage concept

Each blade of grass is cut several times in succession, shorter each time.

Mulching action

Mulching takes place on the ground, not in the air



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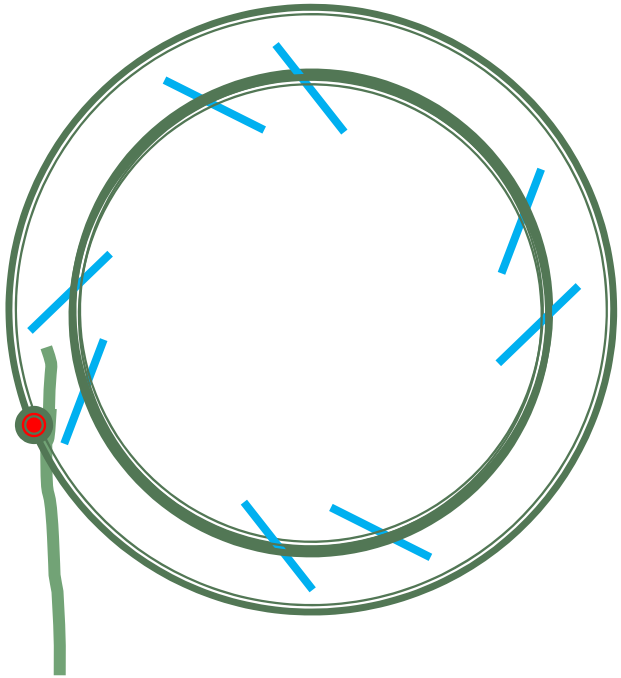

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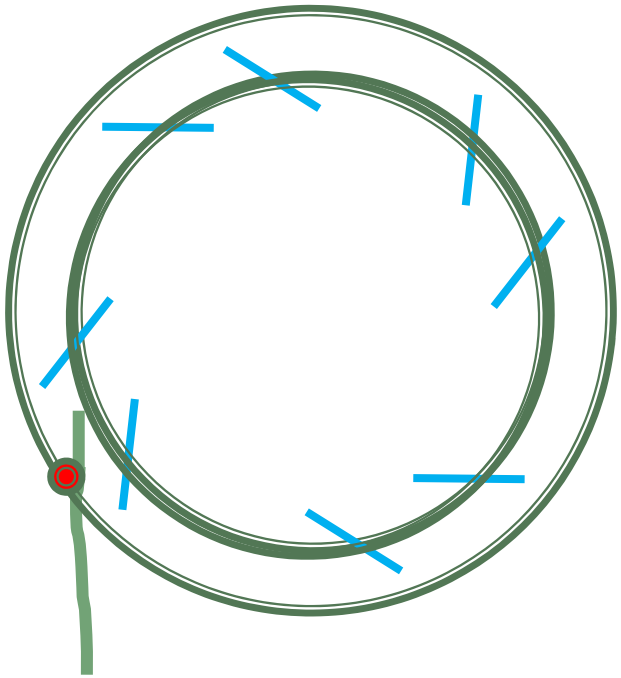

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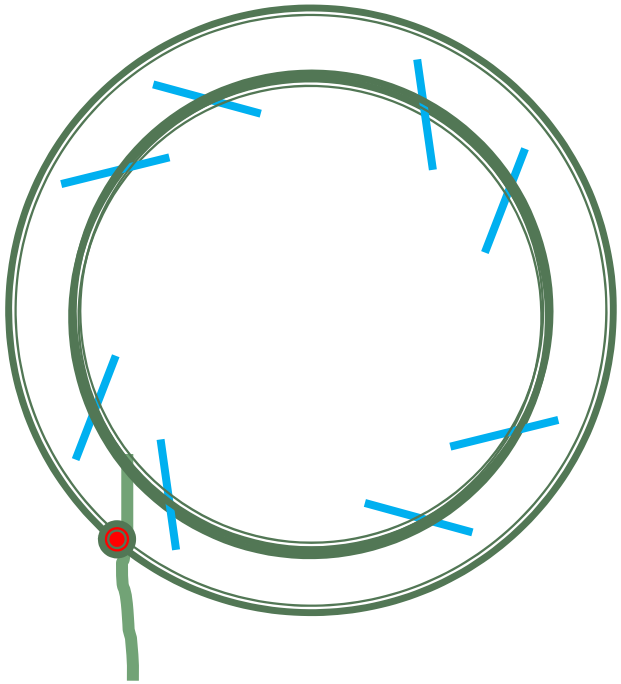


Early (intuitive) decisions

Reel diameter: ≈8”

Cutting width: ≈21”

Blade material: spring steel

2004

Initial format

- 7 evenly-spaced reel bars
- Concentric rotor with 2 or 4 counter-rotating blades. (2 blades = fewer parts but higher speeds to cut same number of clippings)
- Odd number of bars and even number of blades spread power requirement so number of blades in contact with bars at any one time is constant.

Implementation #1

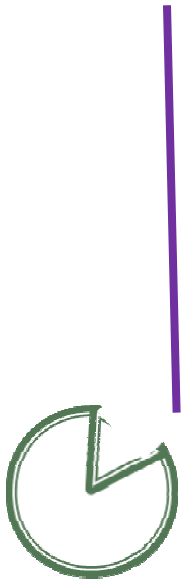
- Helical blades at low angle to straight reel bars
  - Scissors-like ‘pinching’ action

- Problems:
  - Jamming
  - Difficult to change blades

2004

Implementation #2

- Straight blades and helical reel bars
  - Blades at 90º to reel bar edge, cut is ‘wiping action’

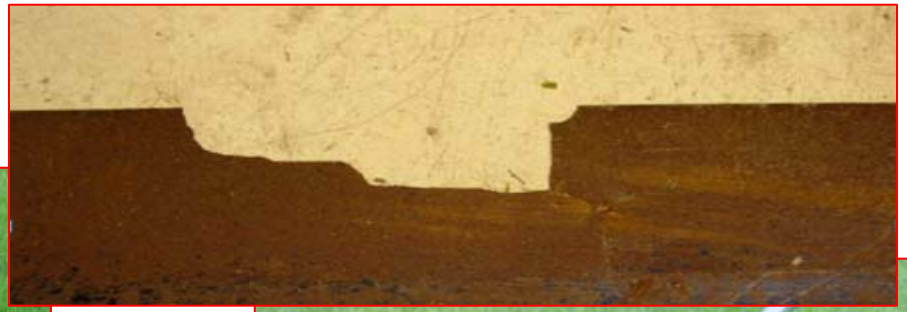


(Self-propelled)

2005/6

Implementation #2 evolution

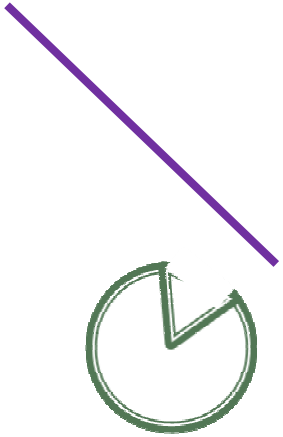
- Mower no longer jams
  - but blades break when encountering large foreign objects (e.g. curbs)



2007

Implementation #3

- Blade at negative angle relative to reel bar
  - ‘soft wipe’ action
- Rotor mounted eccentric to reel

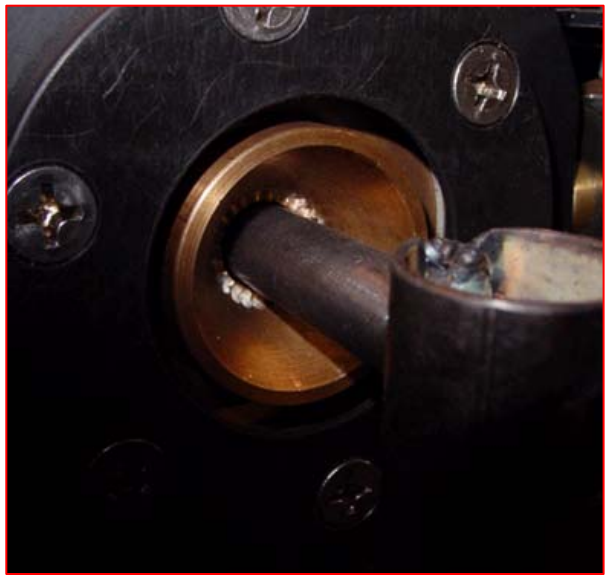


  - No jamming
  - No excessive blade stress

2008/9

Additional challenges

- Heat treating curved reel bars – long thin parts with asymmetric cross-section – without warping them:



Current design

- 8” reel
  - 150 rpm
- 4-blade rotor
  - 450 rpm
  - 21 ½” blade width
- Adjustable blade extension
  - Compensates for wear
- Variable battery capacity

Current design

Current design

Current design

Performance testing

- Objectives of ICAT grant
  - Test cut quality
  - Test energy consumption
  - Test mechanical reliability
  - Test ‘real world’ commercial viability

Cut quality

- Not there yet, but getting close

Variables that affect cutting

- Reel diameter and width
- Reel bar angle
- Reel bar curvature
- Reel bar cutting edge position and twist
- Blade angle
- Blade length, width and material

- *Changing one may require changing some or all of the others.*

Energy consumption tests

- Two tests
  - Small area / heavy cut
    - 20 min.
  - Large area / light cut
    - 60+ min.

- 21.5" O-Sage vs. new 19" B&D rotary electric
  - 24 volt motor
  - 19 Ah capacity lead acid batteries
  - Identical high-capacity battery charging units
  - Identical power meters

· 24 volt motor
· 17 Ah capacity lead acid batteries

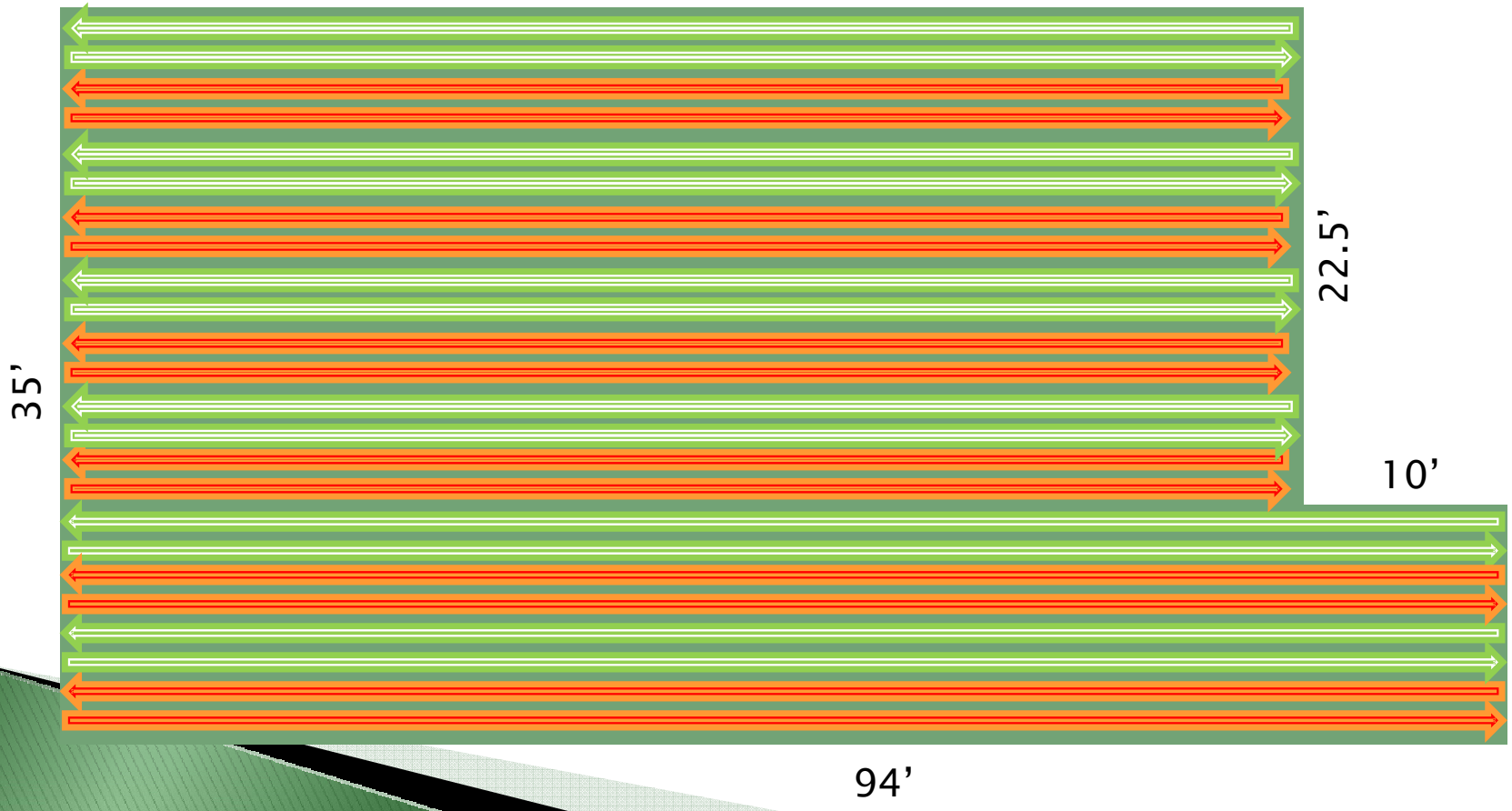
Test #1

- Cut height set at 1 3/8”
- Grass height – moderate

- Similar initial meter readings

Test #1 (cont.)

- Inter-leaved mower paths w/ slight overlap
- Total distance traveled: 1,050 ft. (each mower)



Test #1 results

Rotary = 2.234 Ahrs.

O-Sage = 1.392 Ahrs.

Δ = 0.842 Ahrs.

….or 38% less energy used by O-Sage mower

Test #1 results (cont.)

Test #2

- Cut height set at 2”
- Grass height – variable, short to long

Test #2 (cont.)

- Lock-step mower paths *w/no overlap*
- Total distance traveled: 8,400 ft. (each mower)
  - 12 laps of 700’ each – meters read at end of each lap

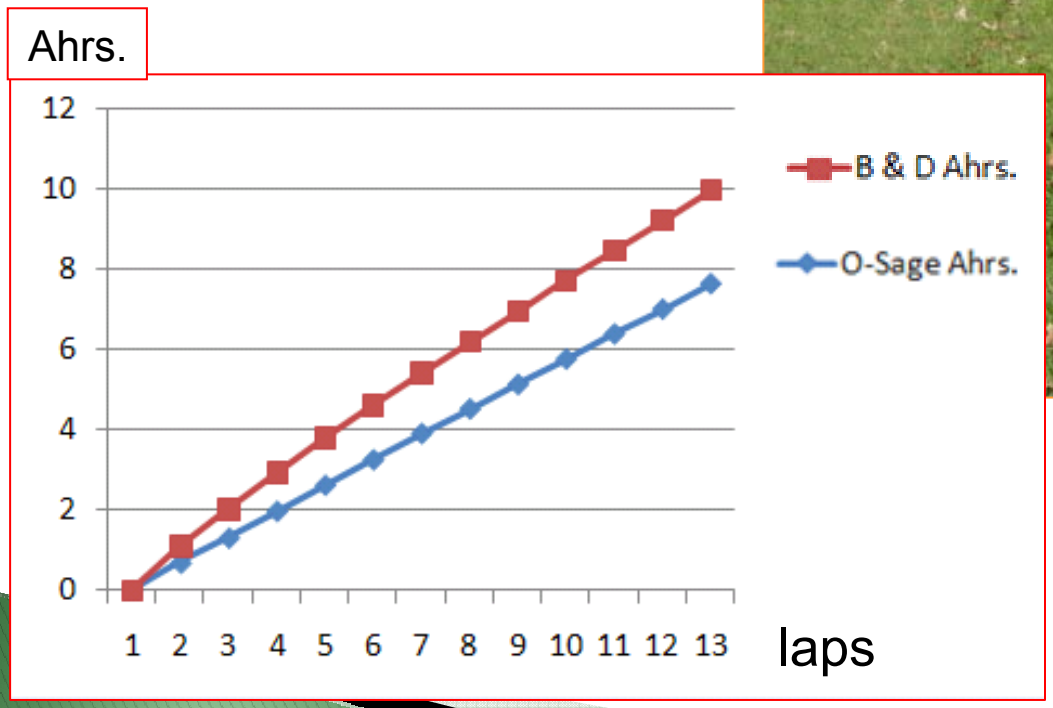
350’

Test #2 results

Run #	O-Sage Ahrs.	B & D Ahrs.	O-Sage V	B & D V
0	0	0	26.35	26.52
1	0.681	1.097	25.9	25.92
2	1.303	2.014	25.72	25.66
3	1.969	2.922	25.61	25.49
4	2.62	3.795	25.38	25.17
5	3.253	4.593	25.17	24.96
6	3.905	5.413	24.98	24.78
7	4.52	6.184	24.87	24.64
8	5.128	6.937	24.8	24.43
9	5.759	7.709	24.71	24.25
10	6.383	8.462	24.62	24.1
11	6.999	9.196	24.52	23.88
12	7.633	9.954	24.45	23.68

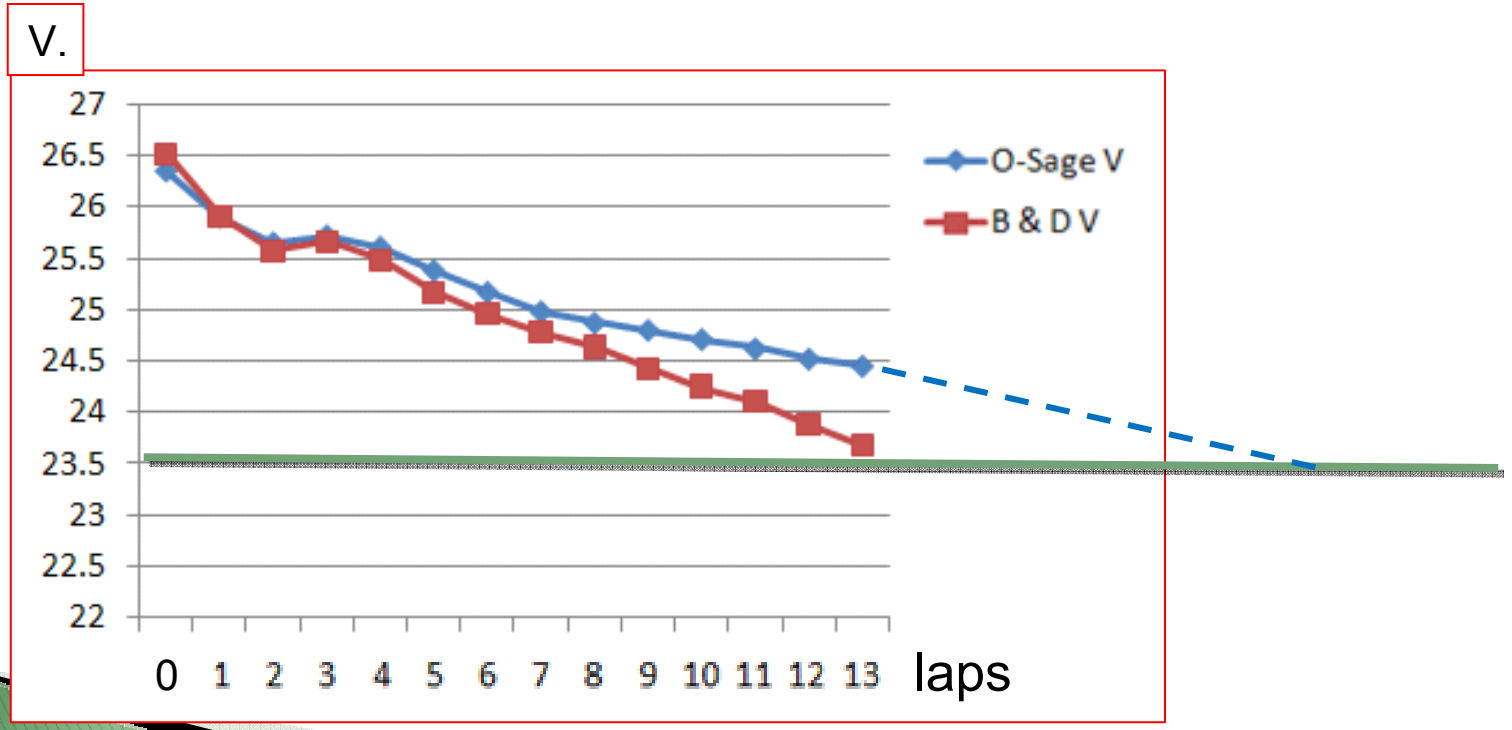
Test #2 results (cont.)

Δ = starts at
0.416 Ahrs. (37.9%)
and ends at
2.321 Ahrs. (23.3%)



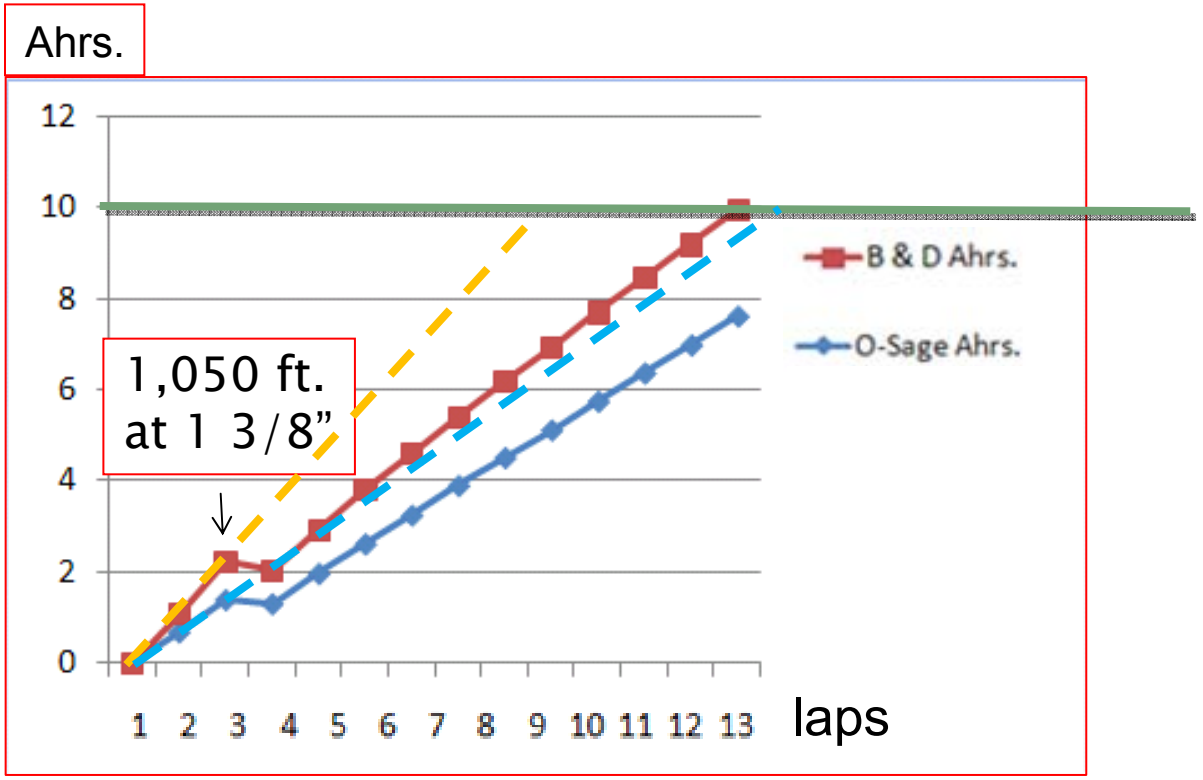
Test #2 results (cont.)

Using rule of thumb that mowing should stop when battery voltage reaches ≈23.5v, the O-Sage mower had substantial reserve.

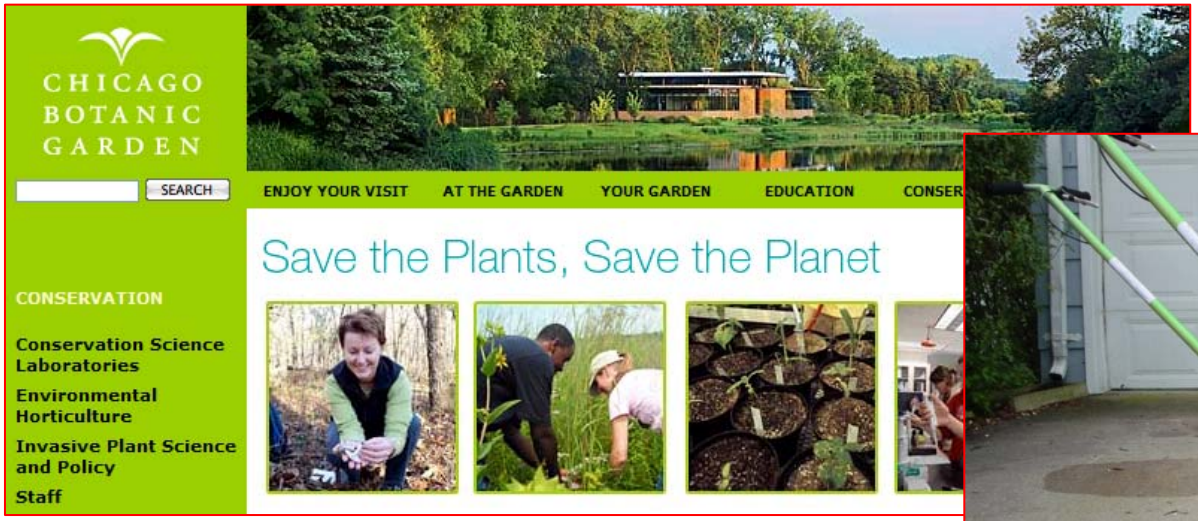


Overlayed test results

Heavier cut substantially reduces run time, but does not reduce O-Sage relative advantage.



Reliability testing



Two mowers sent to the Chicago Botanic Garden for use by grounds maintenance crews during fall of 2009.

Reliability testing

Mowers run up to 2 hours per charge when cut is light

100%

Prototype A

Total hrs.

Broken solder joint

Reel bar jam

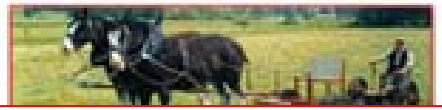
Prototype B

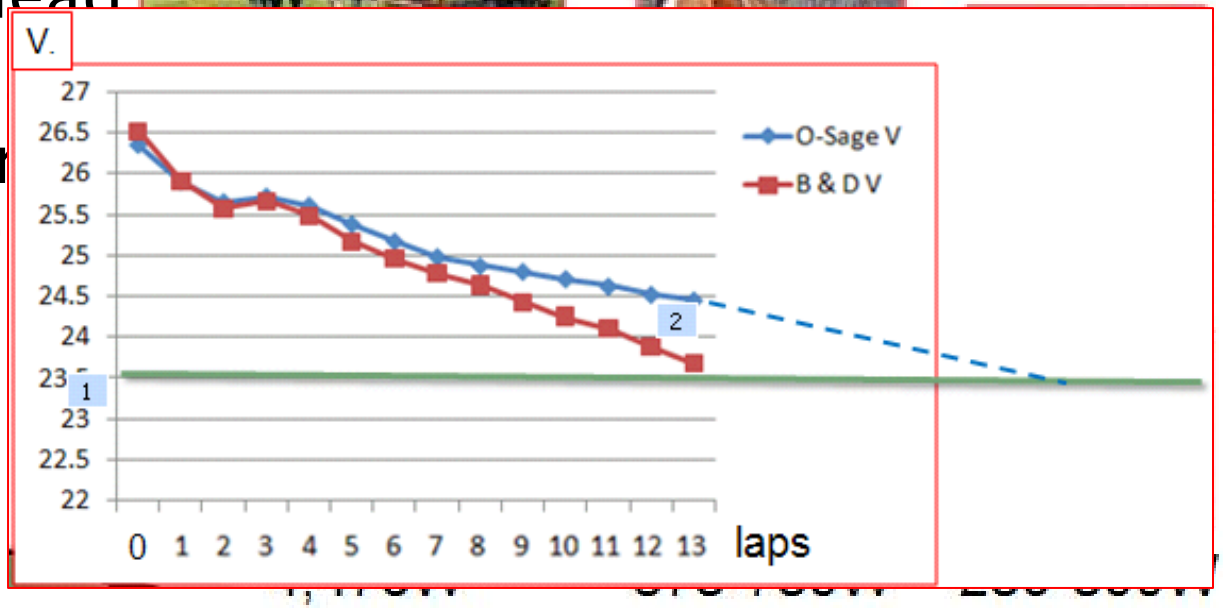
Total hrs.

● Events

Design objective scorecard

- Clean cut – as good as reel mower
- Mulches
- Fraction of energy
- Battery power
- Cutting head
- Easy to U
- Safer thar
- Self-shar blades
- ? No more mower





Potential pollutant reduction

A peer-reviewed study in 2001* found that 54 million Americans use 800 million gallons of gasoline per year to cut their lawns.

The result is the generation of 7,700,000 metric tons of greenhouse gases, as well as 2,620,000 metric tons of other pollutants.

30.28 litres of petrol fuel used for lawnmowing

○ 2-stroke ◉ 4-stroke ≈

Calculate

	Total	Units
Particles (g)	194	grams
PAHs (g)	22	grams
Lead (g)	0	grams
Nitrogen Dioxide (kg)	0	Kilograms
Sulphur Dioxide (kg)	0	Kilograms
Carbon Monoxide (kg)	18	Kilograms
VOCs (kg)	8	Kilograms
Greenhouse Gases (kg)	77	Kilograms

http://www.3sc.net/solarm/gasp.htm

* Roger Westerholm, Ph.D, June 1, 2001
Environmental Science and Technology

Potential pollutant reduction

The US EPA estimates that lawn mowers account for almost 5% of air pollution from all sources…

…and that the replacement of every 500 gas mowers with non-motorized mowers would spare the air of

- 212 pounds of hydrocarbons (smog ingredient)
- 1.7 pounds of nitrogen oxides (smog ingredient)
- 5.6 pounds of irritating particles
- 1,724 pounds of carbon dioxide

6 million new mowers are sold every year

Lessons learned

It's always harder -- and takes longer -- than you think.

Next steps

- Optimize cutting parameters

(winter, 2009)

- Finalize reliability testing
- Finalize design of beta version
- Finalize and circulate business plan

(spring, 2010)

Discussion